Developing Communications Traffic Profiles for the Mobile User Objective Satellite System

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Defense Information Systems Agency
Lt Col Daniel L. Collins, USAF, Ph.D.
Thomas Graziano

MITRE Corporation
John Wilson, Ph.D.

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EXECUTIVE SUMMARY

The Navy Communications Satellite Program Office (PMW-146) has overall responsibility for executing the procurement of the Navy's communications satellites. The Navy plans to replace the current Ultra High Frequency Follow-On (UFO) satellite constellation with a new narrowband system called the Mobile User Objective System (MUOS) starting in 2007. In order to acquire a system that has adequate but not excessive capacity, the MUOS program requires knowledge of satellite access demand to a level of detail sufficient to determine scenario based capacity requirements.

To detail these requirements, a Defense Information Systems Agency (DISA) and support contractor team developed and demonstrated a capability to generate anticipated MUOS satellite access demand for a potential user subset. This subset consisted of a Navy Carrier Battle Group (CVBG) operating in a Southwest Asia major theater war (MTW) scenario. By using the Emerging Requirements Data Base (ERDB) as a basis for developing Information Exchange Requirements (IERs), "traffic profiles" were developed based on how Warfighters are expected to use MUOS in actual combat situations.

The use of a scenario, the development IERs from the ERDB, the utilization of an automated traffic generation tool tied to a relational data base, and the employment of a domain expert panel were all essential elements of the effort. Within a ten hour period, the team was able to produce 20,472 records (transmissions) representative of a Navy CVBG employing 18 MUOS networks defined in the ERDB.

Analysis of the results revealed some networks with apparent excess throughput requirements and others that may not be sufficient to meet anticipated Warfighter demands.

INTRODUCTION

The Navy Communications Satellite Program Office (PMW-146) of the Program Executive Officer for Space, Communications and Sensors located in San Diego, California has overall responsibility for executing the procurement of the Navy's communications satellites. Today, the Navy's Ultra High Frequency (UHF) Follow-On (UFO) constellation provides narrowband satellite communications to the Warfighter. The UFO constellation, initially launched in 1993, is projected to begin to reach its end of life in the early 2000s. The Navy has developed an acquisition strategy to replace the UFO constellation with a new narrowband system starting in 2007. The new system, designated the Mobile User Objective System (MUOS), will provide higher data rates (up to 64 kilobits per second), greater capacity, and greater mobility - it will be accessible by users with handheld terminals.

In support of the MUOS program, the Defense Information Systems Agency (D2 and D8 Directorates) with the assistance of its support contractor team, the MITRE Corporation and SAIC, developed and demonstrated a capability to generate anticipated MUOS demand by a Navy Carrier Battle Group (CVBG) operating in a Southwest Asia major theater war (MTW) scenario. The CVBG consisted of nine surface ships, three submarines, 20 F/A-18s, eight non-combatant aircraft, eight helicopters, cruise missiles, an Explosive Ordnance Disposal Team, and two Sea Air Land/Special Operations Forces (SEAL/SOF) teams.

ROLE AND LIMITATIONS OF THE DOD EMERGING REQUIREMENTS DATA BASE

A major problem that occurs whenever satellite architectures and designs are formulated is to adequately determine projected capacity and utilization requirements. Such is the case for the MUOS. The Department of Defense (DoD), recognizing this problem, initiated an effort to solicit current and future satellite communication requirements from the Services, Agencies, and Unified and Specified Commands. The inputs regarding future requirements were collected and entered into a database called the Emerging Requirements Data Base, or ERDB, and were validated by the Joint Requirements Oversight Council (JROC). The data base is maintained by the Defense Information Systems Agency (DISA) and the requirements collection process managed by the Joint Staff J8.

The ERDB contains information such as required data rate, type operation (half duplex, full duplex, etc.), service availability (e.g., on call, dedicated), connectivity (e.g., point-to-point, netted), protection, mode (voice, video, data), priority, and duty cycle for each uniquely identified link or net. Units (members) participating in a net are also identified by unit type/name. Network participants (usually the Service network control participant) are responsible for generating ERDB network entries and submitting them into the ERDB approval process. Updates occur biannually.

Unfortunately, the ERDB lacks the detailed information needed to determine expected network traffic flow that must be considered in designing a satellite system to meet user demand in real world scenarios. Specifically, it does not provide:

- The communications operational tempo that varies with the scenario
- The information exchanged over a given network and the associated volume of traffic that must be accommodated by a network at any given time or over a period of time
- When, and how often, the information is actually injected into the network
- Who is actually sending and receiving information at any given time

This type of information is referred to as a traffic profile and the process of obtaining such information is called traffic profiling. Obtaining the anticipated traffic profile for the MUOS or any future satellite system is critical to ensuring that the system is designed to efficiently accommodate user demand.

DISA APPROACH TO GENERATING TRAFFIC PROFILES FOR THE MUOS

DISA and the MITRE Corporation developed a process for creating communication system traffic profiles that begins with the ERDB. Initially, the requirement for generating traffic profiles arose from a desire to model the expected performance of the Defense Information System Networks (DISN) when subjected to significant loading from a major contingency. There were a number of good commercial network models available but traffic loading to drive the models was lacking. Generally, the models were capable of generating generic traffic profiles using various algorithms but it is nearly impossible to correlate these profiles to real world contingencies that can stress communication networks in unpredictable ways. What was needed was a way of anticipating and documenting traffic that was scenario dependent. The approach to generating this traffic includes three essential elements or activities:

- Identifying and documenting Information Exchange Requirements (IERs) for a given scenario and mapping them to networks in the ERDB
- Developing and utilizing a tool for generating traffic profiles base on IERs
- Utilizing a panel of domain experts to establish communication traffic patterns in an operational context

Use of Information Exchange Requirements

To meet this need, MITRE developed a process to generate scenario dependent traffic profiles based on the concept of Information Exchange Requirements (IERs) and Information Exchange Products (IEPs). An IER is an identified requirement for two or more units to exchange information concerning a particular subject. IERs are characterized by subject matter, a sender, receiver(s) (may be multiple recipients), time of transmission, and frequency of transmission (how often a transmission occurs). An IEP is the actual information that is transmitted and is characterized by subject name (e.g.,

Situation Report) and size in kilobits for data or a call duration (minutes or seconds) for voice.

Key to our approach to generating MUOS traffic profiles was the linkage of IERs/IEPs to the narrowband satellite networks contained in the ERDB. By examining the narrowband networks in the ERDB, it was possible to associate an IER or IERs with a network. These associations were documented in the MITRE developed relational data base tool called the Communications Support Planning Tool (CSPT). The CSPT was used to record each request for satellite access based on a postulated scenario. The actual process for populating the CSPT and is described later.

Use of The Communications Support Planning Tool

The CSPT provides a mechanism for developing communications traffic profiles and analyzing traffic characteristics. The underlying CSPT relational data base application is an IBM/LOTUS product, called APPROACH 97®, that runs on a Pentium desktop computer under Windows 95/98 or Windows NT. A user friendly graphical interface to the data base application was developed to permit easy entry of key data elements necessary to fully characterize a transmission. The data elements that must be entered are: 1) the information sender or "Agent", 2) the information receiver Agent(s), 3) an information exchange product (IEP), 4) the number and frequency of products sent, 5) the time each IEP is sent, and 6) the net over which the product is transmitted. Macro instructions (macros) were written that automated the generation of multiple transmissions, either on a random or periodic basis. Each transmission was automatically recorded in the CSPT constituting a data base "record".

After the data was entered, the CSPT was used to display information such as the number of transmissions over MUOS over a 24-hour period; the total number of transmissions by network or unit; the number of transmissions during any particular hour by network or unit; and the hour in which the maximum number of transmissions occur. The CSPT provided the complete traffic profile necessary for modeling system performance.

Use of Domain Experts

The traffic profiles obtainable with the CSPT are only as good as the input data. To ensure that the input data was as accurate as possible, multiple sources and methods were used; however, the primary resource used to reflect how individuals nets were employed in a combat situation was a panel of experts with Service experience. For the MUOS demonstration effort, the panel of domain experts (logistics, combat aircraft, search and rescue, etc.) were drawn from individuals within the DISA and contractor team. The panel made decisions (sometimes after consultations with outside experts) on what information was sent over what net, when and how often, to whom, and, in the case of voice transmissions, how long each transmission lasted. All this information was recorded in the CSPT.

THE MUOS TRAFFIC PROFILING PROCESS

The four step process followed in generating MUOS traffic profiles is illustrated in Figure 1.

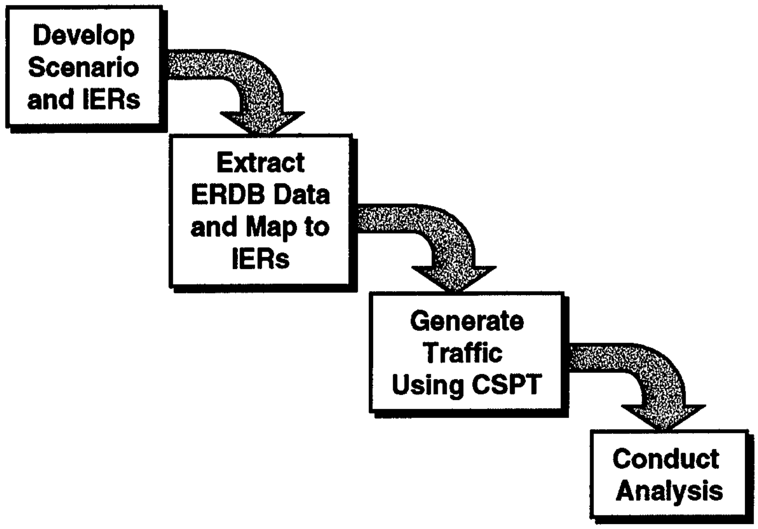

Figure 1. The Four Step Process in Generating MUOS Traffic Profiles

Step 1 - Develop Scenario and IERs

The first step was to define in more detail the Southwest Asia scenario and select a particular day from that scenario that would be expected to place a heavy demand upon the MUOS. The day selected was Day 120 (24 hours) when forces were fully engaged. There were two highly stressed periods during the day: hours 0800 to 1100 and 1800 to 2100. The combat and supporting activities that were expected during the chosen day were fully described and "time-stamped" by hour. These activities were further examined to identify those that required the transfer or exchange of information over a tactical narrowband satellite communications system. The result was a set of IERs.

Step 2 - Extract ERDB Data and Map to IERs

The second step was to associate particular IERs with MUOS networks and the CVBG units likely to employ the narrowband networks listed in the ERDB. This was done by taking the list of IERs developed in Step 1 and mapping them against units and/or networks in the ERDB that were likely to transmit the content of the IER. For example, the IER "request to be rescued" coming from a downed pilot with a survival radio (SR) would be sent over the Combat Survivor Evader Locator (CSEL) net. The SR transmission consists of a pre-set number and sequence of bits sent periodically that constituted the IEP. Now a connection has been established between the scenario, the IER/IEP, the projected MUOS network, and an operational unit or units.

Step 3 - Generate Traffic Using CSPT

The third step was to create the MUOS traffic profile by recording in the CSPT the basic characteristics of each transmission during the selected scenario day (24 hour period). These basic characteristics were the IER, the sending unit, the receiving unit (or units for netted operations), the network utilized, and the time of transmission. For data transmissions, the *size* of the IER (defined as an Information Exchange Product (IEP) measured in bytes) was defined, and for voice transmissions, the duration of each call was recorded in the CSPT. There were four sources for this data: the ERDB, data collected through interviews and questionnaires, data collected from documents and data bases, and personnel with operational communications experience – our domain expert panel.

CSPT macros were used to create multiple transmissions or records. For example, the "random transmission" macro was used to generate multiple transmissions at random times (elapsed time in seconds from 0000) once a start time and number of desired transmissions was entered. Similar macros were used to create transmissions that were sent periodically throughout the day.

To create the MUOS traffic profiles, the domain expert panel met for about 10 hours over a period of two days. This was sufficient to create approximately 20,000 voice and data transmission records originating from 91 units employing 18 different networks. This represents approximately one tenth of the total ERDB narrowband satellite nets.

Step 4 - Conduct Analysis

The fourth step was to analyze the entered data. CSPT permits sorting and displaying data in several formats. It was used to show information such as the number of transmissions over MUOS over a 24-hour period; the number of transmissions by network or unit; the number of transmissions during any particular hour by network or unit; and the hour in which the maximum number of transmissions occur.

ANALYSIS RESULTS

The process and tools described above enabled the DISA team to developed traffic profiles showing demand for satellite access (in kilobits for data, call minutes for voice) for each of the 18 networks during each scenario hour. An example of the results for one network, the CSEL, is shown in Figure 2.

The scenario used to generate this profile involved the downing and rescue of four pilots as follows:

1. Four F/A/18s downed between 0300 and 0430. Pilot 1 downed in water and transmits 609 bits at 0330, repeats every 30 minutes. Picked up in two hours (0530 is last transmission).
2. Pilot 2 downed on land. Begins to transmit at 0445 and is rescued at 1045 (last transmission). Transmission size and frequency same as pilot 1.

3. Pilot 3 downed on land. Begins to transmit at 0315 and is rescued at 0920. Transmission size and frequency same as pilot 1.

4. Pilot 4 downed in water. Begins to transmit at 0420 and is rescued at 0630. Transmission size and frequency same as pilot 1.

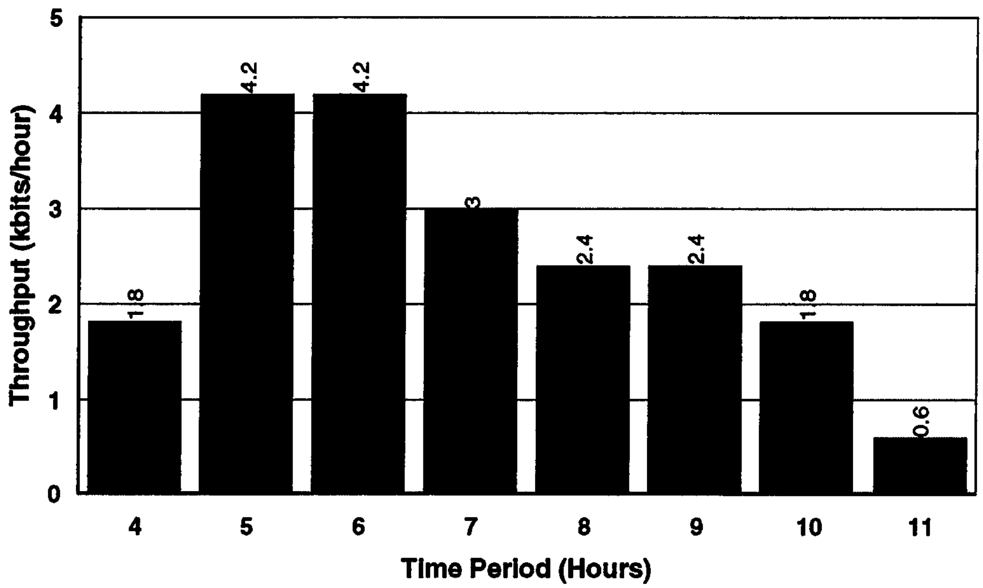

Figure 2. Traffic Profile for the Combat Survivor Evader Locator Network

This figure shows that the CSEL network throughput requirement is relatively small. It would be desirable in designing a satellite system to provide a capability to access this net on demand but not tie up a channel all the time. Figure 3 illustrates the effect of dedicating a net to this function in comparison to providing an on-demand capability.

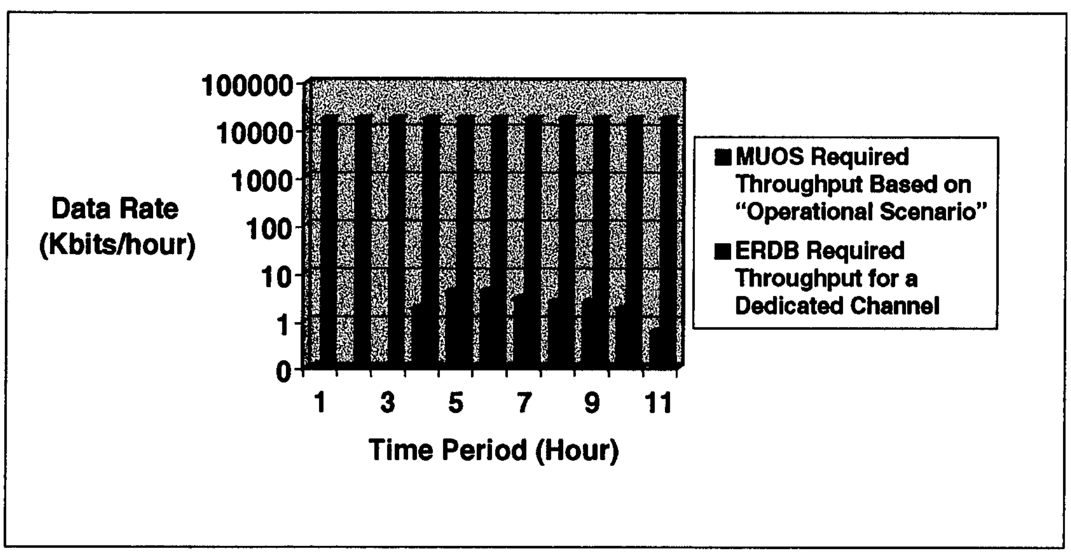

Figure 3. CSEL On-Demand Requirement vs. Dedicated Net

SUMMARY

The DISA team developed a process and tool that was used successfully to generate MUOS data and voice traffic profiles for a typical CVBG in a combat scenario. The use of a scenario, the development IERs from the ERDB, the utilization of an automated traffic generation tool tied to a relational data base, and the employment of a domain expert panel were all essential elements in the success of the effort. The team was able to generate a MUOS scenario based data set quickly and efficiently. Within a ten hour period, the expert panel was able to produce 20,472 records (transmissions) representative of a CVBG employing 18 MUOS networks identified from the ERDB. Analysis of the results revealed some networks with apparent excess throughput capacity (e.g. CSEL) and other networks that may not have sufficient capacity to meet the demand (e.g. LAMPS).